White Paper

Impact of 5G on 4G Services for Operators and NEMs

This white paper provides key information about the impact of 5G on 4G services in multiple scenarios and the test requirements needed to make 5G NSA a success.

Introduction

5G is gathering momentum at a pace not experienced with legacy technologies such as 3G and 4G. In fact, a growing number of operators that have existing LTE networks have now launched 5G, according to the GSA. We've already seen a great deal of investment in 5G, and we'll see a growing number of operators targeting the enterprise market to support applications in agriculture, manufacturing, automotive and healthcare. It is anticipated that an acceleration of 5G roll-out will take place throughout 2020, particularly with non-standalone (NSA) designed to work with existing 4G networks.

However, introducing 5G NSA presents a risk to the QoS for 4G LTE. 4G networks can be adversely affected as they are upgraded to accommodate interworking with 5G for NSA. This is a concern because operators' primary focus is consumer connectivity, and the majority of user equipment (UE) in circulation is only compatible with 4G LTE.

Despite the investment in 5G, 4G is still evolving. A new breed of low complexity UE is emerging, including devices which run on narrowband IoT (NB-IoT) and CAT-M up to 3GPP Release 15. Enhancements to networks must therefore be made to support low complexity UEs, in order to provide better throughput, latency and power consumption. 4G LTE still remains a significant source of revenue for operators, meaning it is vital to maintain the Quality of Service (QoS) for 4G LTE users.

This paper will examine some of the challenges that operators and NEMs face when evolving their networks, with a particular focus on the impact 5G will have on 4G services.

We also present a number of use cases which highlight some of these challenges, and conclude with advice on how operators can mitigate degradation to the QoS for 4G users.

Challenges of Maintaining 4G as 5G Evolves

Managing Frequent gNB and eNB Software Upgrades

The development of 5G NSA requires operators to also update the 4G eNB, as it is acting as the anchor for UEs supporting Dual Connectivity with 5G New Radio (NR). The updates involved mostly concern signaling (including UE capabilities), connection reconfiguration, and the ability to handle mobility and handover scenarios. New 4G features are also being added by 3GPP, such as higher order carrier aggregation (CA), higher order modulation schemes in the uplink (256QAM), and new UE categories for higher throughput UEs.

At the same time, 5G gNBs are being updated with new features such as multi-user MIMO and voice over NR. They are also being developed in conjunction with a growing number of UEs.

Achieving these advancements requires frequent updates of 4G eNB and 5G gNB software, which makes the maintenance of the network challenging. As a result, the QoS of existing 4G users may be compromised, because as more features are added, more loading is put in the 4G eNB. This problem will quickly escalate as more users (including low complexity UEs) are added to the network.

Maintaining Network KPIs as 5G Evolves

As 4G and 5G NBs are updated with new features, NEMs must test the interaction between these new additions. However, as the 5G standard evolves and grows ever-more complex, the interactions between these features also becomes a lot more complex. This makes the NEM's job of network testing increasingly difficult.

As end users move in different environments with different types of traffic, they will require dynamic networks that can deliver different feature combinations in order to ensure a high QoS. Importantly, these combinations must deliver the best possible network efficiency in terms of resource utilization.

A good example of technology that can help achieve a high QoS is multi-user MIMO, which enables a network to share radio resources by exploiting the spatial characteristics between multiple users. At the same time, carrier aggregation may be enabled to provide the best possible throughput. The operator must be confident that the network provides a stable and consistent QoS to users in multiple different scenarios. While it's possible to enable some network features for a single user, there are thousands of other users experiencing different environments, traffic and capacity scenarios, fading and spatial conditions. This presents a major challenge for operators, which must ensure that their networks can cater for multiple users in these different environments.

Operators do not consider it their responsibility to test which network features are enabled depending on the user environment; instead, the onus for this is on the NEM. However, operators do care about what happens at the application layer where the user QoS is measured.

As 5G NSA evolves, operators must define KPIs to ensure a consistent QoS and ensure these KPIs are maintained. As the number of users increases, it may be necessary to optimize the network to ensure that the KPIs are met, as greater demands are put on processing. Operators will look to select equipment from vendors that they know can guarantee the delivery of new 5G features, as and when they are available.

Handling an Increasing Number of Legacy and New Low Complexity UEs

Another challenge facing operators concerns the management of a multitude of diverse, low complexity UEs. The evolution of 5G has not stalled the introduction of new types of 4.5G Cat-M and NB-IOT devices, which are now up to 3GPP release 15. These can impact network performance from a capacity perspective, as low complexity UEs transmit bursts of traffic or small packets which can put heavy demands on e/gNB processing. As more UE types are added onto the 4G leg, the pressure mounts on the operator to ensure that 4G QoS for legacy users is not compromised.

Operating 4G with 5G O-RAN

The aim of introducing disaggregated networks is to standardize interfaces between vendor e/gNBs and to allow operators to use low cost, off-the-shelf hardware. It also presents opportunities to optimize disaggregated network elements. While the benefits for the operator are clear, O-RAN also presents a major challenge, as operators may integrate different disaggregated network elements from different vendors.

Consider a gNB radio unit (RU), distributed unit (DU) and central unit (CU), all of which are provided by different vendors. The software updates may not be synchronized, as the different equipment vendors may release software – including upgrades on the 4G eNB – at different times. While the multi-vendor objective has been met, the end-to-end performance of the network is at greater risk. Operators are therefore tasked with ensuring interoperation of software releases while at the same time guaranteeing that the end user is unaffected.

Use Cases that Depict 4G-5G Operator Challenges

In this section we outline a number of example use cases that highlight the risks operators face. Each of the listed examples can adversely impact the QoS for 4G users.

4G-5G Interaction with Capacity

Consider a capacity test scenario where the LTE cell is fully loaded with UEs doing CA, as well as NB-IOT UEs and other UEs doing MU-MIMO with VoLTE traffic. The eNB handling 4G as part of 5G NSA provides the control signaling for the UE attach, and higher layer procedures responsible for connection establishment. At the same time, the gNB is loaded with thousands of UEs with different traffic types, including HTTP, FTP, and HD video.

The NEMs would usually test different types of traffic and capacity scenarios in the lab. They will also look to set up test scenarios that really push the network to the limit. So, for example, not only testing 700 or 800 UEs – all of which are sending small packets of data, which quickly amounts to a high volume of traffic – but testing 1,000-plus. This could be an example of a point at which the system may fall over, meaning testing is really taken to the edge!

With field testing, the operator's main concern is user experience, and achieving the required QoS may involve optimization before deployment. This may involve tweaking local or system parameters to maintain the QoS for 4G users which may now be affected as a result of the additional control signaling imposed by 5G NSA. If this is not taken care of, the 'ping rate' of the operator's network could be adversely affected. Other practical risks include dropped calls or users finding it difficult to establish a connection. 4G users may also find that the voice quality of calls is not as expected, or there is a delay in downloading content.

Load Balancing

5G NSA adds complexity in terms of the types of handover that can occur between 4G and 5G. In 5G terminology, the 4G eNB is called the master eNB (MeNB) and the 5G gNB is termed the secondary gNB (SeNB). So, from a handover (HO) perspective, a user can experience the following HO scenarios between the NBs:

1. MeNB1 to MeNB2
2. MeNB1 to SeNB2
3. Cases #1 and #2 in reverse
4. MeNB1 and SeNB1 to MeNB2 and SeNB2
5. MeNB1 and SeNB1 to MeNB2
6. Cases #4 and #5 in reverse

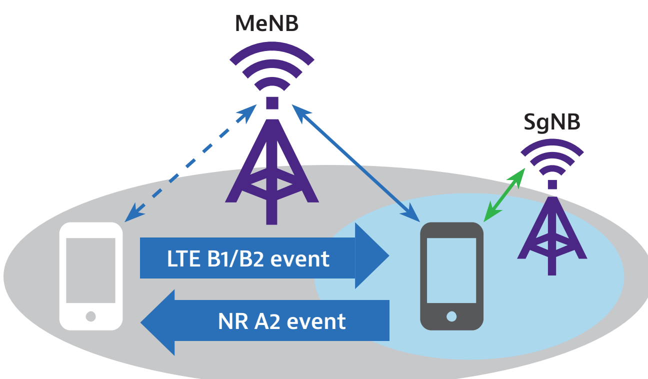

Figure 1

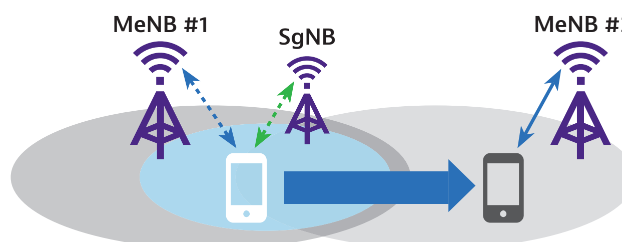

Figure 2: LTE A3/A4/A5 event with NR measurement results

LTE A3/A4/A5 event with NR measurement results

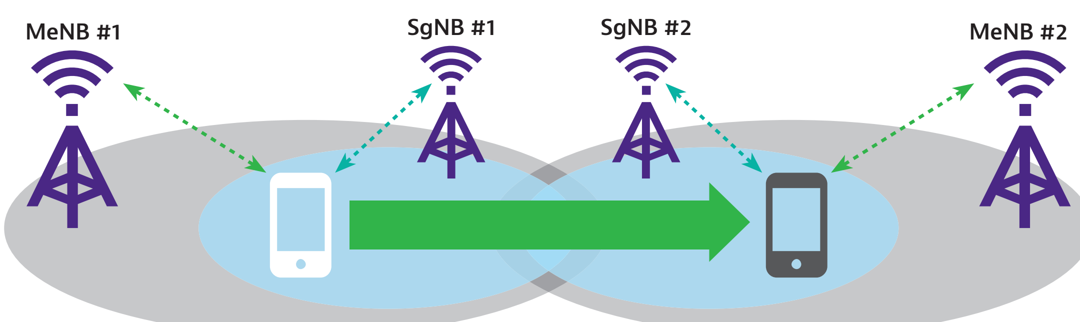

Figure3: UE moves from MeNB #1 / SgNB #1 to MeNB #2 / SgNB #2

These handover scenarios, at scale, would increase the signaling load on the 4G eNB. As a result, users may observe lulls in throughput due to delays in the processing of control signaling information for handovers.

The growing number of handsets in circulation could also determine the QoS of the 4G user. Let's say a user decides to keep their current 5G handset for years to come. As more 5G users are added for NSA, the 4G user may experience a degraded 4G service due to the eNB handling more control signaling. However, if the 4G user upgrades to a 5G handset, both the 4G and 5G users may in the end observe a better QoE, for the following reasons:

1. Heavy traffic users could be offloaded to the 5G cell, freeing up resources on the 4G cells. This means that a 4G user who has not upgraded their handset to 5G would benefit from an improved QoS overall.
2. The user who has upgraded to a 5G handset will simply enjoy the higher data rates and lower latencies offered by 5G.

In any of the above cases, testing for load balancing is important in order to provide a good QoS for both the 4G and 5G user. This could require an operator to optimize the network and ensure that the load balancing is fair to both types of user, while QoS is maintained or even improved. The operator has to ensure that at the point of load balancing, the service is not interrupted and there is no drop in throughput.

High Call Attempts

The call attempt success rate is a key metric for e/gNB acceptance in some ecosystems, and is particularly important under high load conditions, due to additional 5G and low complexity UEs. The call success rate in an LTE cell can be affected in the same way that we've seen with NSA. High load conditions can also place more pressure on congestion control to reject or bar UEs which may need to be optimized to improve or maintain the QoS.

How to Ensure 5G Does Not Undermine 4G Services

In this section we present the means by which NEMs and operators can maintain or even improve the QoE for 4G users as 5G is introduced, using a number of example cases.

Testing to Optimize 4G Networks

The growing number of 5G handsets entering the market will put a strain on 4G services, and on control signaling in particular, causing users to experience a deterioration in the responsiveness of the network. This case is more likely in high load scenarios, especially as more IOT UEs are added to a 4G network. Such scenarios must be addressed by NEMs and operators.

NEMs must test the networks under stress conditions with the latest features and UE types as requested by operators. New NB-IOT and Cat-M UEs, for example, have been introduced, which are 3GPP compliant and designed to be more responsive, faster and consume less power. These must be tested in loaded conditions alongside standard UEs which support VoLTE and normal cellular traffic. This will enable operators to identify the corner cases, as well as the most common cases where performance degradation is seen. Networks can then be optimized to improve elements like the control signaling or the transaction rates for the eNB serving as the anchor for 5G NSA.

Operators will have to ensure 4G services are unaffected by the addition of 5G users, including optimizing networks to protect 4G users who have not upgraded their handsets to 5G.

One way to avoid compromising 4G users who have 5G-capable handsets and who use lots of data, is to offload them to 5G networks. This would create space for 4G users who have not upgraded their phones. In order to achieve this, the operator would need to do an end-to-end test to optimize the network, including load balancing, to ensure the best thresholds are set.

Testing to Maintain or Improve KPIs

NEMs and operators typically set KPIs that determine network performance and QoS, ranging from cell throughput, maximum number of UEs that can be connected to a cell, latency, jitter, and round-trip times. Establishing such KPIs helps operators ensure that, as more low complexity UEs are added to the network, the QoS for 4G users is not adversely affected.

The rapid development of 5G means many new functionalities and features are being added not only to the 5G network, but also to 4G. Software network upgrades may be more frequent, adding to the risk that KPIs will not be met. The only solution to this is for operators to run more frequent network testing to ensure that, as more functionality is added to the network, they continue to deliver on those all-important KPIs.

For NEMs, it's more important at this stage to ensure that the 4G KPIs remain uncompromised, over and above 5G KPIs. Why? Because protecting 4G QoS (and thus revenue) will help fund development and deployment of 5G.

For example, an operator may have previously conducted optimization work to improve the QoS for 4G users, and will want to ensure that the issue faced originally will not be repeated with the next network software upgrade. The operator may also want to ensure that new device types added to 4G networks are operating at peak performance and do not adversely impact other users. Frequent network testing is therefore crucial to ensure that 4G users remain happy.

Ensuring Repeatable Performance and Stability

NEMs need to ensure that a repeatable performance is obtained when 4G and 5G are working concurrently. They must make sure that they are testing not only the 4G-5G interaction with regards to 5G NSA, but also the full feature and capacity load set involving users which are experiencing different environments and applications.

This can be achieved by testing in a lab environment and running multiple test cases to ensure a repeatable performance as eNBs are upgraded. It is important to test not only for repeatability in performance but also for stability. This will enable NEMs to find out where eNBs may experience a crash, to put in measures to handle this scenario, and to implement enhancements to ensure a seamless eNB recovery.

Ensuring adequate testing is predominantly the remit of NEMs. However, operators may also want to ensure stability for new services over 4G, as new device types are added to the network.

Ensuring Overall Network Performance with O-RAN

O-RAN has allowed players to develop different disaggregated network components. However, managing software upgrades and ensuring a consistent and reliable performance across the network is challenging. One solution is for an operator or NEM to invest in a single vendor which will provide the equipment needed to test disaggregated network components. Operators and NEMs must also consider the following:

1. Invest in a vendor with leadership and experience in 4/4.5G to ensure the interoperation of 4G and 5G as 5G evolves. This is owing to the complexity of deployment topologies with legacy technologies.
2. Invest in a wireless test equipment vendor with extensive experience and a strong track record as the vendor of choice in major ecosystems in which eNB and gNBs from different vendors are evaluated. This instills trust if a vendor is seen to have a large install and usage base.
3. Investing in a partner who has worked and is working with many vendors, and can accommodate a wide variety of requirements as concerns O-RAN. This is because although O-RAN is standardized, there are some aspects of O-RAN (such as with O-RAN fronthaul) that can be vendor specific.

Concluding Remarks

We're currently in the early stages of 5G development and deployment, which emphasizes feature development and network performance. It is easy to get caught up in the hype around 5G, and rightly so: the benefits 5G can offer to multiple technology sectors and application verticals are huge.

However, 4/4.5G is still evolving, and 5G handset use – although set to increase through 2020 – is still far from widespread. Until we reach this point, 4/4.5G users will continue to make up the vast majority of operators' subscriber bases and will continue to contribute significant revenue for operators. This inevitably means that NEMs and operators will need to take measures to protect, and in some cases improve, the QoS for 4G users, through rigorously tested load balancing techniques.

Although 5G will bring many benefits, it also adds complexity and risk to 4/4.5G users which must be mitigated well in advance, with adequate interoperability testing, achieving peak performance and network optimization.

References

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